AN IMPROVED EMITTER-COUPLED MULTIVIBRATOR

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I. INTRODUCTION

An interesting transistor multivibrator analog to a vacuum tube cathode-coupled type was presented in Ref. 1. The advantages of this multivibrator include the possibility of faster operation with given transistors, a simpler circuit, elimination of the recovery effect to give square waveforms, less dependence on power supply variations, and a completely free collector.

In order to demonstrate the practicability of such a multivibrator for clock-pulse generators, test equipment, etc., to frequencies over 10 megacycles, the circuit is analyzed. The frequency is shown to be a function of the ratio of collector-to-emitter supply voltages. A modification of the circuit is described which utilizes this fact to advantage; such a circuit is shown which has a total frequency variation of less than one percent for ±50 percent change in supply voltage.

II. ANALYSIS OF THE CIRCUIT

The circuit is shown in Fig. 1(a) and its waveforms in Fig. 1(b). Assume Q_1 is conducting and Q_2 is off. The emitter current of Q_1 is split into a current, i_1, and a charging current, i_2; i_2 reduces the voltage on the emitter of Q_2, illustrated in Fig. 1(b). Eventually, the base-emitter threshold voltage of Q_2 is exceeded. Q_2 starts to conduct, and some of the current flowing in R_4 is diverted to Q_2.

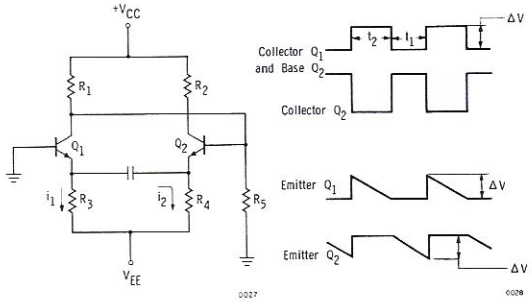

FIG. 1a. The improved emitter-coupled astable multivibrator.

FIG. 1b. Waveforms of the multivibrator.

Thus, the emitter current of Q_1 falls, the collector voltage of Q_1 and the base voltage of Q_2 rise, and Q_2 conducts more heavily. This regenerative effect then flips the circuit to the other state. A similar effect eventually brings the circuit back to its original state.

The analysis of the circuit can now be made and is separated into two parts: Q_1 on for time t_1, and Q_2 on for t_2.

Let us first write approximate equations for the case Q_1 on as shown in Fig. 2(a).

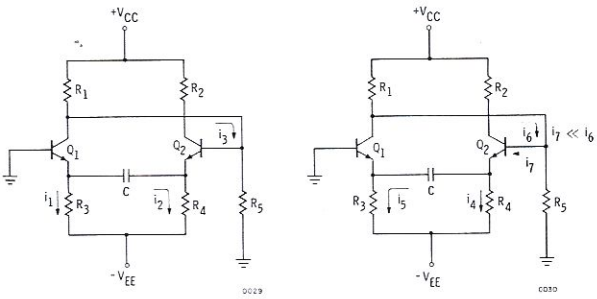

FIG. 2a. Currents for Q_1 **on** and Q_2 **off.**

FIG. 2b. Currents for Q_1 **off** and Q_2 **on.**

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$$V_{E_1} = i_1 R_3 - V_{EE} = V_{BE}(sat) \quad (1)$$

$$V_{E_2} = i_2 R_4 - V_{EE} \quad (2)$$

$$i_2 = C \frac{\Delta V}{t_1} \quad (3)$$

$$\Delta V = V_{E_2} - V_{E_1} = C \frac{\Delta V}{t_1} R_4 - V_{EE} + V_{BE}(sat) \quad (4)$$

$$\Delta V = \frac{V_{CC} R_5}{R_1 + R_5} - \left[\frac{V_{CC} - (i_1 + i_2) R_1}{R_1 + R_5} \right] R_5 = (i_1 + i_2) R_p \quad (5)$$

where

$$R_p = \frac{R_1 R_5}{R_1 + R_5}$$

The time t_1 can now be solved

$$t_1 = \frac{C R_p (R_3 + R_4)}{(R_3 + R_p)} \quad (6)$$

Let us now write the approximate equations for the case Q_2 on as shown in Fig. 2(b).

$$V_{E_1} = C \frac{\Delta V}{t_2} R_3 - V_{EE} \quad (7)$$

$$V_{E_2} = i_4 R_4 - V_{EE} = - V_{BE}(sat) + V_{B_2} \quad (8)$$

$$V_{B_2} \simeq \frac{V_{CC} R_5}{R_1 + R_5} \quad (9)$$

$$\Delta V = V_{E_2} - V_{E_1} = \frac{V_{CC} R_p}{R_1} - C \frac{\Delta V}{t_2} R_3 + V_{EE} - V_{BE}(sat) \quad (10)$$

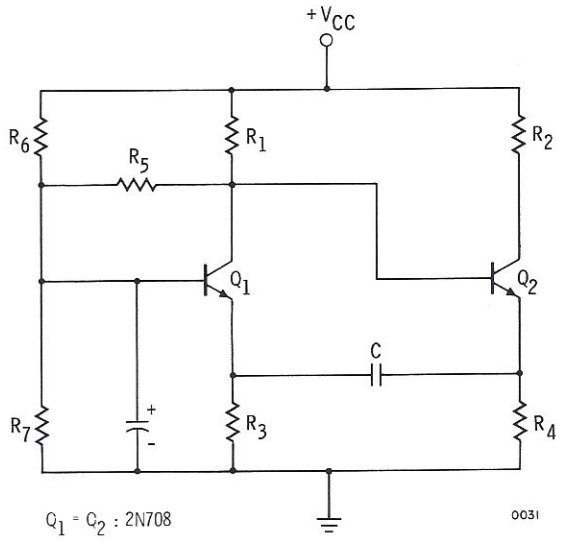
The time t_2 can now be solved

$$t_2 = \frac{C (R_3 + R_4)}{\left[\frac{V_{CC}}{V_{EE} - V_{BE}(sat)} \right] \cdot \left[\frac{R_4 - R_p}{R_1} \right] + \frac{R_4}{R_p} - \frac{R_4}{R_3} - 2} \quad (11)$$

Also, ΔV can be calculated, and

$$\Delta V = \left[V_{EE} - V_{BE}(sat) \right] \left[\left(1 + \frac{R_4}{R_3} \right) // \left(\frac{R_4}{R_p} - 1 \right) \right] \quad (12)$$

Note the very important result that t_1 is independent of power supply voltage and t_2 is dependent only on the ratio $V_{CC} / \left[V_{EE} - V_{BE}(sat) \right]$. This indicates the possibility of obtaining multivibrators having very good frequency stability, unlike all other types, with widely varying power supply voltages, as long as the ratio of collector and emitter supplies is constant. This constancy can be assured by using only one supply and by deriving the base reference voltage from a resistive divider. Such a circuit is shown in Fig. 3, and its frequency dependence on V_{CC} is shown in Fig. 5.



$Q_1 = Q_2$: 2N708
R_1 : 0.47 KΩ
R_2 : 0.5 KΩ
R_3 : 3.3 KΩ
R_4 : 4.7 KΩ
R_5 : 0.47 KΩ
R_6 : 0.39 KΩ
R_7 : 1 KΩ

FIG. 3. Practical circuit of emitter coupled multivibrator.

III. PRACTICAL CIRCUIT

A practical circuit using only one power supply is shown in Fig. 3, and the waveforms in Fig. 4.

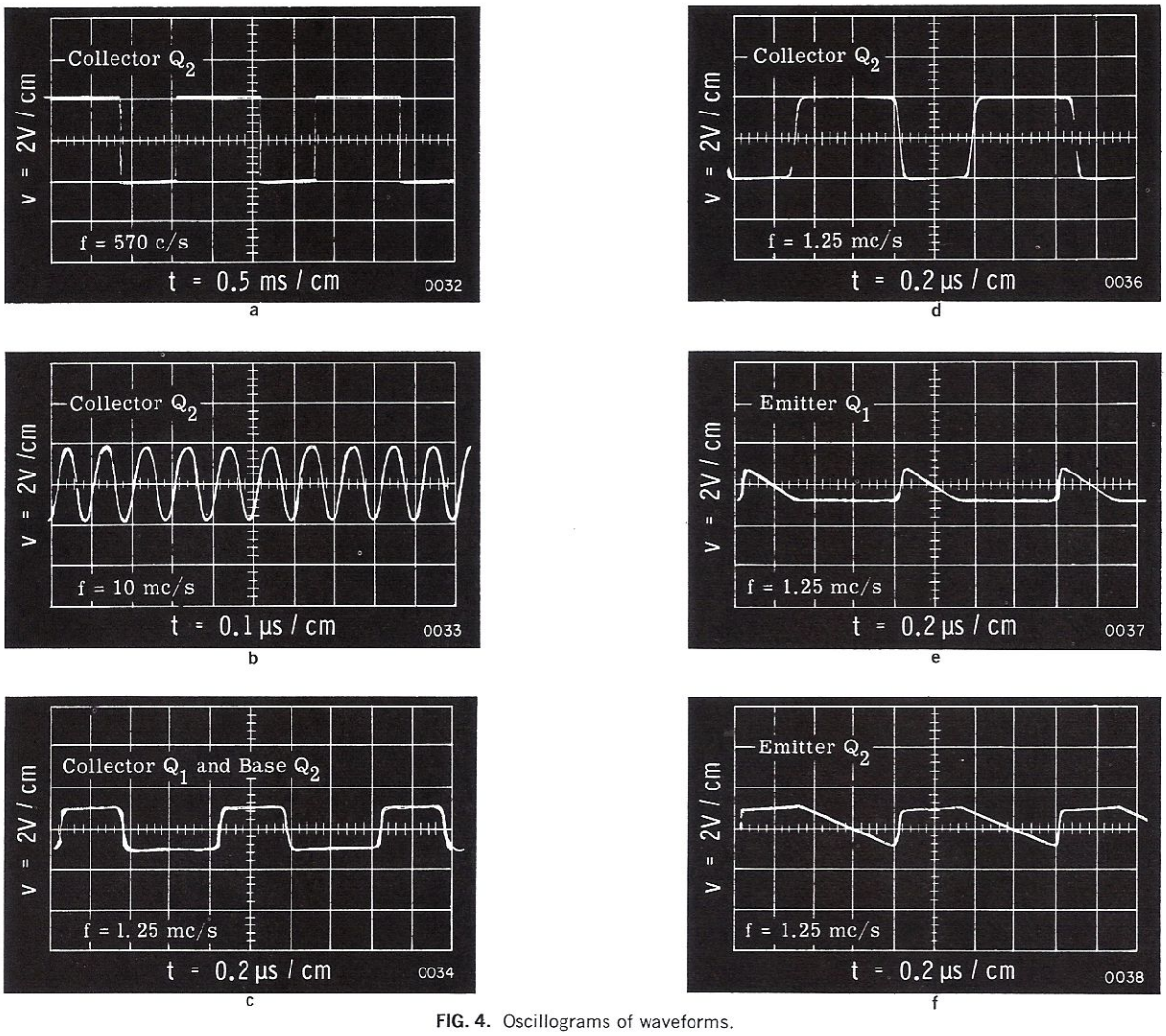


FIG. 4. Oscillograms of waveforms.

The transistors used were 2N708's. The frequency dependence of the circuit at a given frequency with respect to the power supply variation is shown in Fig. 5. A ±50 percent change in supply voltage varies the frequency by less than one percent overall (-0.35 to +0.56 percent) as measured on a counter without, unfortunately, a time-interval feature; a better counter might well reduce this figure even further.

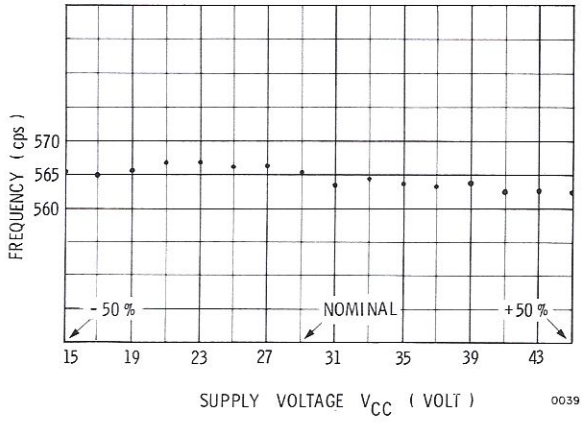


FIG. 5. Frequency with respect to power supply variation.

IV. CONCLUSION

The emitter-coupled multivibrator is seen to be a considerable improvement over conventional types for reason of waveform, frequency stability, independent output and others.

It is expected that in many applications it can prove to be very useful.

ACKNOWLEDGEMENT

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REFERENCE

1. R. L. Foglesong (Fairchild Semiconductor), "Current Switching Astable Multivibrators," Electronic Equipment Engineering, Circuit Design No. 34, p. 41, December 1961.